Changing Pathways to a Bomb

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Abstract

While a large literature has theorized about the decision of states to develop nuclear weapons, few scholars examine pathways to a weapon—how states actually go about building a bomb. The conventional wisdom has been that states subject to nuclear safeguards would use undeclared, secret facilities to produce the highly enriched uranium or plutonium necessary for nuclear weapons. The example of Iran, however, suggests that this view may need to be reevaluated. I theorize that broad changes in nuclear proliferation dynamics make would-be proliferants more likely to pursue a latent nuclear capability—acquiring technology that brings them just to the edge of having a nuclear weapon—than to pursue a covert weapons effort. My findings have important implications for the international community's efforts to limit the spread of nuclear weapons technology in the future.

The vast academic literature on nuclear proliferation focuses almost exclusively on why states pursue nuclear weapons. But *how* states actually go about developing nuclear technology may be even more important in tailoring nonproliferation policy. This paper examines state pathways to nuclear weapons pursuit, with a focus on the decision to make use of secret or overt nuclear infrastructure. I argue that the preferred pathway to proliferation—long thought to be a small, covert nuclear weapons program—is changing, and that future proliferating states will be more likely to repurpose civilian nuclear facilities for weapons purposes. This shift has a number of important implications for designing effective policies to limit the spread of nuclear weapons.

This paper proceeds in three parts. First, I discuss the literature on the means of nuclear pursuit and describe the possible drivers of the selection of one pathway over another. Next, I theorize about changes in the dynamics of nuclear proliferation that might lead states to prefer an overt nuclear infrastructure for nuclear development. Third, I describe several implications of my argument for nonproliferation policy.

How states seek nuclear weapons

While there is a large international relations literature on the drivers of nuclear proliferation, including a recent renaissance in quantitative studies of nuclear pursuit, few social scientists have addressed *how* states go about developing nuclear weapons. In a notable exception, Narang (2017) offers a typology of possible strategies of proliferation employed by states seeking at least a future nuclear option. Narang associates each strategy with a set of technical decisions by states, arguing that strategic choices dictate a particular technical path to a weapon. For example, a “sprinting” strategy emphasizes speed, and states pursuing this strategy will therefore develop nuclear facilities that are explicitly for military use. A “hiding” strategy, on the other hand, leads to secret facilities that are more easily concealed. Narang does not address, however, the possibility that the optimal technical choices for a particular strategy may change over time. “Hiding” states, for example, may find that overt facilities—rather than smaller, secret nuclear sites—are the best way to conceal the existence of a nuclear weapons program.

A related literature examines the link between civilian nuclear capability and nuclear weapons pursuit. Concerns about whether nuclear power would spur nuclear proliferation date back to the very beginning of the nuclear age. Studies of civilian nuclear assistance—both nuclear cooperation agreements between states and multilateral nuclear assistance from the International Atomic Energy Agency—show that this assistance is associated with an increased likelihood of nuclear weapons pursuit (Brown and Kaplow 2014; Fuhrmann 2009, 2012). Nuclear power itself, however, does not appear to lead to nuclear proliferation in most cases (Miller 2017).

Though long a concern of scholars and analysts (Wohlstetter 1976), the literature recently has renewed its focus on latent nuclear capability—the capacity to produce nuclear weapons quickly if the decision is made to do so. Leveraging new data on the subject (Fuhrmann and Tkach 2015; Smith and Spaniel 2018; Spaniel 2019), scholars have examined what factors lead to increased nuclear latency (Mehta and Whitlark 2017b), and how nuclear latency can affect international outcomes of interest (Mehta and Whitlark 2017a; Spaniel 2019; Volpe 2017). This literature represents an important step in disaggregating nuclear capability, treating nuclear proliferation as more than just the presence or absence of nuclear weapons.

An applied literature uses the tools of decision analysis and technical assessments of fissile material production costs to better understand how states will go about seeking weapons (Ahmed and Husseiny 1982; Heising 1982; Silvennoinen and Vira 1981, 1986). The goal of much of this work was to develop more proliferation-resistant nuclear energy technology, but the technical pathways literature also offered a number of policy recommendations for those interesting in limiting the spread of nuclear weapons. This work has played an important role in developing the inspection approaches used the International Atomic Energy Agency (IAEA) to verify existing nuclear facilities in a state and to monitor potential diversion of nuclear material for military purposes (Anzelon et al. 2014; Kim, Renda, and Cojazzi 2015).

Nuclear pathways

States can acquire nuclear weapons in a number of ways. Pathways analysis has traditionally focused on three major factors that determine the route to a nuclear weapon: the choice of fissile material, the ability to acquire nuclear weapons technology from foreign suppliers, and the use of secret or overt nuclear facilities.

Nuclear weapons require either highly enriched uranium (HEU, containing a high percentage of uranium-235) or plutonium. HEU is produced by mining uranium ore, processing the ore into yellowcake (uranium ore concentrate), converting yellowcake into a form suitable for enrichment, and then increasing the concentration of the uranium-235 isotope through one or more of several possible enrichment processes.

Plutonium is created in nuclear reactor fuel, usually fed by natural or low enriched uranium, then separated from the fuel through chemical reprocessing. A state's decision to use highly enriched uranium or plutonium for its first nuclear weapons helps determine the types of facilities it will need, the size of its nuclear infrastructure, and its ability to conceal this infrastructure from other states (Ullom 1994).

Outside assistance can substantially influence a state's pathway to a nuclear weapon. At one extreme, the acquisition of a completed nuclear device from a weapon state—whether willingly given or illicitly smuggled—may obviate the need for the development of any nuclear infrastructure at all. There has been speculation, for example, that Pakistan might be willing to provide Saudi Arabia with a nuclear weapon should Iran ultimately acquire a nuclear capability (Hoodbhoy 2015). States may also seek to acquire from abroad highly enriched uranium or plutonium, leaving only weaponization to be completed indigenously.[1] States frequently have acquired full fissile material production facilities—including enrichment plants, nuclear reactors, and reprocessing facilities—from nuclear suppliers, easing the path to the development of

[1] There is a clear trade-off between taking advantage of foreign assistance pathways to nuclear weapons development and the ability to field a large nuclear arsenal. Acquisition of a single weapon or enough fissile material for a small number of weapons is plausible, if unlikely. Larger quantities of material almost certainly would require a separate nuclear infrastructure, absent a cooperative production arrangement with a supplier state.

nuclear infrastructure. This assistance has sometimes been intended by the supplier to spur weapons work—as was likely in the case of the North Korean-built nuclear reactor in Syria, for example (Office of the Director of National Intelligence 2008)—but more frequently has been provided under at least the plausible cover of civilian nuclear research or power infrastructure (Fuhrmann 2008; Kroenig 2009). Foreign assistance with technology development can ease the path to building indigenous nuclear infrastructure, leading states to pursue particular pathways to a weapons capability. The AQ Khan network, for example, provided centrifuge technology and other sensitive information to several states, including Iran and Libya (Fitzpatrick 2007).

Finally, because of the dual-use nature of nuclear technology, states seeking weapons face a choice between using secret facilities or repurposing civilian infrastructure for nuclear weapons development.[2] States may adopt a fully covert fuel cycle, using secret facilities to enrich uranium or to produce and reprocess plutonium. The early nuclear weapons states fall into this category; the presence of nuclear sites in the US and Soviet Union during the 1940s and 1950s were considered state secrets. More recently, states such as Iraq, Libya, and Syria have pursued weapons programs covertly. States also may produce fissile material for a weapon entirely at sites declared

[2] Civilian nuclear sites are usually, but not exclusively, associated with a nuclear power program. A large number of states also possess facilities designed for research and technology development or the production of radioisotopes for medical or agricultural applications.

to be part of a nuclear power program. India, for example, used a Canada-supplied power reactor to produce fissile material used in its 1974 test of a nuclear device. An overt nuclear infrastructure enables both a *hedging* strategy, in which the state maintains the option for weapons development in the future (Levite 2003; Narang 2017), and a *breakout* strategy—the use of declared facilities to produce fissile material for a weapon, without regard for the risk of detection. Alternatively, states may employ a mix of these two approaches—a *diversion* strategy—for example by producing low-enriched uranium at a declared site associated with a civilian power program, then further enriching that material to weapons grade at a secret facility.

It is this last factor—the choice of overt or covert facilities for fissile material production—that is the focus of this paper. Figure 1 shows how different states have approached these pathways to nuclear development. Each line shows a nuclear weapons program.[3] Blue bars represent the use or intended use of overt facilities to produce fissile material for nuclear weapons, while states with red bars sought to use secret nuclear sites to produce such material. Lighter bars represent nuclear weapons pursuit, and darker bars denote time periods in which states have acquired nuclear weapons.[4] The figure shows significant variation in the pathways chosen by states seeking nuclear weapons. A narrow majority made use of a fully covert nuclear weapons effort, but many

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[3] Nuclear weapons program dates are updated from Jo and Gartzke (2007).

[4] Please see the supplementary file for a detailed description of coding decisions for each case of nuclear pursuit.

employed or intended to employ overt nuclear facilities, especially since the 1970s. Two states changed their chosen pathway in the midst of the weapons effort.

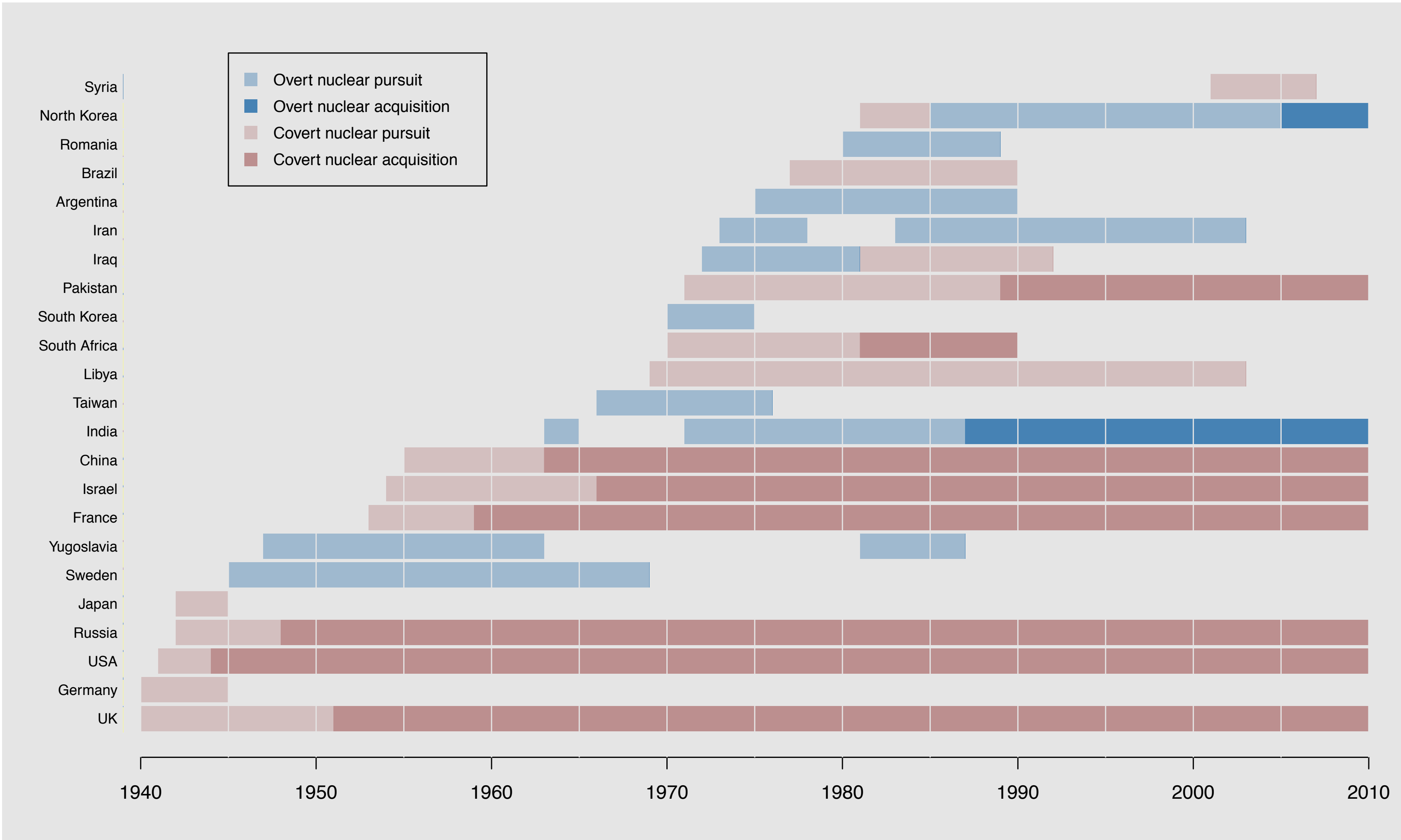
The overt versus covert decision touches on a central tradeoff faced by would-be nuclear weapons states between speed and secrecy. Pursuing a covert nuclear infrastructure is likely to slow nuclear development for several reasons. First, there is the basic physics of fissile material production. All else equal, larger facilities can produce more material more quickly than smaller sites, but of course larger facilities are also more easily detected.

Second, covert programs are likely to advance more slowly because the pool of technical expertise and resources are necessarily limited by the requirements of secrecy. Civilian nuclear development can draw on experts from the private sector, research institutions, government agencies, and even foreign companies, but secret programs typically rely on a much smaller cohort of technical experts who can be vetted for work on military programs. In a similar vein, covert programs have a smaller set of possible foreign suppliers who will be willing to contribute to the program's development. Nuclear programs that at least maintain the appearance of civilian research or nuclear power goals can plausibly receive assistance from the full range of nuclear suppliers.[5]

Third, the need for secrecy may dictate technical choices that extend nuclear timelines or even make successful nuclear weapons acquisition less likely. Covert

[5] Foreign supply may not always speed nuclear development, although governments tend to behave as if it does. See Montgomery (2013).

Figure 1: Overt versus covert pathways for nuclear weapons pursuit



programs, for example, might focus on gas centrifuge uranium enrichment—because centrifuge facilities have few external signatures and can be more easily concealed—when a plutonium production reactor would be a more expeditious pathway to weapons-usable fissile material.

In some cases, pursuit of a particular nuclear outcome may demand the use of overt or secret nuclear site. For example, states that are undecided about whether to pursue a weapons capability, and that simply want to maintain the option to do so in the future, may naturally seek a hedging strategy that emphasizes civilian nuclear infrastructure. But in other cases, more than one pathway to a weapon could plausibly address a state's strategic goals.[6] In these situations, what leads states to choose one pathway over the other? States weigh the relative costs of each pathway against its benefits. We can simplify this calculus to three broad factors that influence the decision to choose overt facilities or covert facilities for fissile material production: the risk that a covert nuclear weapons effort will be detected, the consequences of this detection, and the relative benefit of a weapon developed via a particular pathway. Changes in these factors make the use of a covert nuclear infrastructure more or less attractive to states.

The greater the chance that a secret nuclear weapons effort will be detected by outside actors—be it an adversary or international inspectors—the more likely a state is

[6] This approach contrasts with Narang's (2017) framework, which links particular strategies of proliferation to particular technical decisions—such as whether to use overt or covert facilities.

to pursue a declared, civilian nuclear infrastructure. Why trade speed for secrecy if covert activities are likely to be discovered regardless? The risk of detection also factors into decisions about whether to divert material from civilian facilities. In most cases, diversion seems more likely to be detected than the presence of covert facilities, simply because international safeguards regimes focus most of their efforts on inspecting declared sites. As the risk of detection increases, diversion scenarios, too, become less attractive than a full breakout scenario.

The consequences states are likely to face if they are detected with a covert weapons program also factor into state decision-making. When the likelihood and severity of a potential punishment for covert nuclear pursuit is high relative to overt pathways, a state is more likely to focus attention on its civilian nuclear infrastructure. Both covert and overt pathways offer opportunities for the international community to punish nuclear weapons pursuit, so an important factor here is the window during which outside actors might take action against the proliferant state. States using an overt nuclear infrastructure may reduce this period of vulnerability by getting as close as possible to producing fissile material for a weapon before attempting work that is clearly linked to nuclear weapons development. This is because acquisition of a nuclear weapons capability makes severe punishment from the international community much less of a risk—no nuclear weapons state has been targeted with an attack on its nuclear facilities (Fuhrmann and Kreps 2010). The shorter this breakout timeline is assessed to be, the more attractive is an overt approach relative to the use of secret facilities.

In addition to these differing costs, one pathway might offer benefits over the other. As suggested above, speed is one oft-cited tangible benefit of an overt approach. Although it has not always worked this way in practice (Miller 2017), states might well expect that the ability to operate openly would lead to an advanced nuclear infrastructure much more quickly than an effort that required secrecy. The size of nuclear facilities, too, might make one pathway more desirable than another. States that are eager to produce a large nuclear arsenal might require a more substantial infrastructure—perhaps more than could reasonably be kept secret—than states that are satisfied with a handful of nuclear weapons. And states may also value the flexibility offered by overt sites; leaders can always switch to a hedging strategy or abandon nuclear weapons ambitions without having to justify wasted resources on facilities that cannot be repurposed.

How nuclear pathways are changing

Analysts and scholars have long assessed that nuclear aspirants would be more likely to take advantage of covert pathways to a nuclear weapon than to seek a nuclear breakout using civilian infrastructure. The logic of this assessment is straightforward. Diversions from overt facilities or the use of declared facilities themselves to produce fissile material for a weapon would be more likely to be detected by outside actors than similar activity at a covert site (Einhorn 2006). Given the consequences of discovery, states are most likely to focus on covert pathways. The US intelligence community made this judgment explicit and public in the case of Iran, writing in the Key Judgments to a 2007 National Intelligence Estimate, “We assess with moderate confidence that Iran probably would use covert facilities— rather than its declared nuclear sites—for the production of highly enriched uranium for a weapon" (National Intelligence Council 2007).

It may be time, however, to revisit this assessment. While states are likely to vary in their calculus of the risks and rewards of secret weapons efforts, broader changes in the dynamics of nuclear proliferation seem to have made the use of overt facilities generally more attractive over time, and especially for potential future nuclear aspirants. In this section, I reexamine each of the factors that influence the choice between overt and covert pathways—the risk of detection, the consequences of detection, and the relative benefits of the overt pathway—to identify how these factors have shifted over time.

The risk of detection

The chance that an undeclared nuclear facility will be detected has increased substantially over time, making covert pathways less attractive to would-be nuclear weapons states. An important driver of this change has been the continuing evolution and strengthening of nuclear safeguards. The most significant changes in nuclear monitoring and verification measures have come in three areas: in the fundamental approach to nuclear safeguards, in the technologies and procedures employed to verify safeguards compliance, and in the scope of coverage of nuclear facilities and materials.

Before the NPT came into force in 1970, IAEA safeguards were generally implemented piecemeal on select nuclear facilities within a country, usually as a condition of sale specified by the nuclear supplier (Jennekens 1990). Under the NPT, member states were required to implement comprehensive or full-scope safeguards, which place all nuclear material in the country under IAEA purview. The need for full-scope safeguards was emphasized by India's 1974 nuclear test, which used nuclear material that had been diverted from civilian facilities provided by the United States and Canada (Tape and Pilat 2008). The resulting safeguards approach of the 1970s and 1980s focused on the verification of state declarations and ensuring that no nuclear material had been diverted from a safeguarded facility (Carlson et al. 1999; Gruemm 1983). The underlying safeguards philosophy shifted again in 1991 with the discovery that Iraq had harbored an extensive nuclear weapons program despite having full-scope IAEA safeguards in force. Rather than focus solely on the verification of state declarations to the IAEA, the mission of safeguards inspectors was expanded to address the completeness of declarations and the possibility of undeclared nuclear activities (Carlson et al. 1999; Goldschmidt 2001; Pellaud 2000; Tape and Pilat 2008).

The Iraq revelations also drove the introduction of new technologies and procedures into safeguards practice. Unattended monitoring systems, for example, saw substantial improvements. The IAEA in the 1970s monitored spent fuel pools using a pair of cameras set to shoot every twenty minutes. Inspectors would attempt to review thousands of black-and-white images at every visit, looking for any sign that the spent fuel had been moved. In the last twenty years, however, the IAEA has deployed more advanced unattended monitoring systems. Today's systems can capture radiation and other measurements as well as images, and in some cases are monitored remotely (Schanfein 2008). While the IAEA has always benefited from satellite imagery provided directly from member states, only recently has it gained the capability to independently order and analyze commercial satellite imagery in support of safeguards goals (Chitumbo, Robb, and Hilliard 2002). Access to satellite imagery is particularly important to identifying suspected undeclared facilities that might merit further investigation (Ferguson and Norman 2010).

Environmental sampling techniques were introduced to IAEA safeguards in the mid-1990s, allowing IAEA inspectors to measure the isotopic composition of nuclear materials, potentially contradicting a state's declarations (Donohue 1998; Donohue, Deron, and Kuhn 1994). Environmental sampling played an important role in building the noncompliance case against Iran. Agency inspectors in 2003 requested access to a suspected, but undeclared, centrifuge workshop. Iran eventually allowed inspections, but only after an attempt to decontaminate the facility—replacing the floor, repainting walls, and moving equipment to other locations. Still, environmental sampling there detected enriched uranium particles that could not be explained by Iran's existing declarations and led to Iran's acknowledgment later that year that it had indeed conducted undeclared centrifuge testing at the facility using nuclear material (Samore 2005).

Safeguards technologies like environmental sampling are only useful if the IAEA has access to nuclear facilities. Such access is granted by means of a comprehensive safeguards agreement between the state and the IAEA. The NPT calls for these agreements to enter into force within 18 months of joining the treaty, but the actual performance of member states in this area has been far worse.[7] Figure 2 shows safeguards adoption over time as a percentage of NPT member states in a given year. The solid line indicates the presence of full-scope safeguards from a comprehensive safeguards agreement of any type. As recently as 1995, only 55 percent of NPT member states had a comprehensive safeguards agreement in force, although total adoption had risen to 87 percent by 2010.

Figure 2 highlights three categories of full-scope safeguards. A comprehensive safeguards agreement grants the IAEA access to nuclear facilities for the purposes of verifying state declarations about nuclear activities. Beginning in 1997, as a response to the undeclared nuclear activities in Iraq, NPT member states were encouraged also to bring into force an Additional Protocol to their safeguards agreement that provides the IAEA with wider access to verify the completeness of state declarations. This includes the requirement to declare nuclear facilities and allow inspections there even when nuclear material is not present, and the wider use of environmental sampling to provide assurances that nuclear material has not been introduced at undeclared sites (Hirsch 2004).[8]

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[7] This requirement applies only to non-nuclear weapons state parties to the NPT. While the P5 nuclear weapons states (China, France, Russia, the United Kingdom, and the United States) have voluntarily implemented safeguards and allowed inspections at some facilities, these are not full-scope safeguards that cover every nuclear facility within the state.

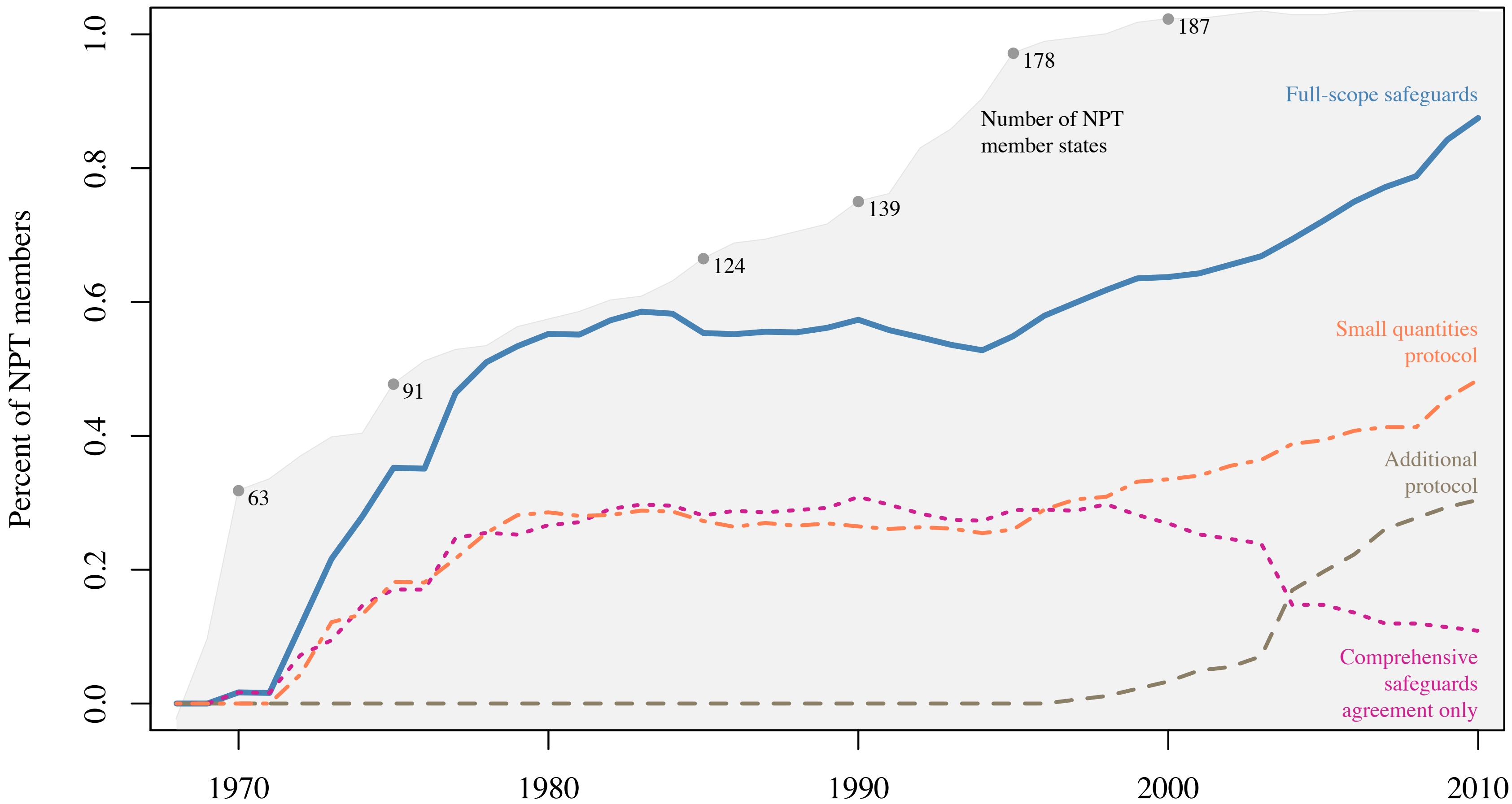
[8] On the importance of the Additional Protocol for limiting proliferation generally, see Schulte (2010).

If the Additional Protocol represents a more stringent level of safeguards access than a standard comprehensive safeguards agreement, then the Small Quantities Protocol (SQP) is a significant step down.[9] For states with quantities of nuclear material below a particular threshold, the SQP reduces declaration requirements and limits IAEA access to facilities within the state. Importantly, there is no mechanism by which the IAEA can seek to verify the state's assertion that it meets the requirements for the SQP in the first place. This represents an enormous loophole in the safeguards system—the IAEA must trust that a state is correctly characterizing its low level of nuclear development, and must rely on the state to notify the IAEA when these conditions no longer apply.[10] The IAEA in 2005 took steps to close this loophole with a modified version of the SQP that allows the IAEA

[9] The Additional Protocol and Small Quantities Protocol are not mutually exclusive. In 2010, 44 NPT member states had both protocols in force. The SQP places limits on IAEA action even when an Additional Protocol is also present, for example waiving the requirement that states provide initial declarations of nuclear materials and activities (Kerr 2005b)

[10] No state has been found to be using the SQP as part of a clandestine nuclear weapons effort. Still, the decision of states like Saudi Arabia to adopt the SQP rather than a standard comprehensive safeguards agreement has aroused suspicion (Kerr 2005b; Perkovich 2008).

Figure 2: Adoption of full-scope safeguards by NPT member states over time



to verify state declarations and, if necessary, conduct in-country inspections (International Atomic Energy Agency 2005b; Kerr 2005a, 2005b).[11]

Overall, the trend in safeguards coverage has been positive, especially since the mid-1990s. Almost all states now have some type of full-scope safeguards agreement in place. After a slow start, a substantial number of states have signed the Additional Protocol, granting the IAEA new tools in its efforts to verify compliance. The introduction of a modified SQP effectively closes the largest remaining loophole in the safeguards system for states that bring the modifications into force. This increased access, combined with a new approach to inspections that makes use of new technologies and procedures, suggests that IAEA safeguards are significantly more formidable today than in decades past.

Another important determinant of the risk that covert nuclear weapons efforts will be detected is the growth in NPT membership over time (the shaded portion of Figure 2). Not only have IAEA safeguards become more effective, but the increase in NPT membership occurring at the same time has made far more states subject to these full-scope safeguards measures. One clear result of the growth of NPT membership is that the IAEA now has substantially more access to nuclear facilities in more states than at any point in the history of the regime. And because nearly any future proliferant would be

[11] Then-IAEA Director-General Mohammed El-Baradei recommended eliminating this type of safeguards agreement altogether, but his proposal was not accepted by the IAEA's Board of Governors (Kerr 2005a).

seeking nuclear weapons as an NPT member state—among non-weapons states, only newly independent South Sudan has not signed the treaty—states will need to adjust their strategy to contend with this greater risk of detection from the beginning of the program. This dynamic is likely to push states to emphasize overt rather than covert efforts.

The consequences of detection

The allure of the covert pathway to weapons is that it allows a state to develop a nuclear weapons capability without permitting adversaries or the international community a chance to respond. One element of the cost of this pathway is the risk that the covert activity is detected; the other is the consequences that the state will bear if its actions are found out before they bear fruit. While the NPT itself lacks formal power to punish violators—a finding of noncompliance with the NPT merits merely a referral to the UN Security Council, for further action at its discretion—the international community does frequently act in a variety of ways to pressure states to stop weapons development efforts. Enforcement tools available to states range from unilateral attempts at persuasion, to global sanctions regimes like those arrayed against Iran and North Korea in recent years, to preemptive military attack.

Empirical studies of nuclear sanctions and other counterproliferation measures highlight some ups and downs, but the pattern broadly points to more reliable punishment over time. The use of nuclear sanctions first emerged as a prominent tool of US foreign policy in the 1970s (Miller 2014). Reynolds and Wan (2012) track 454 sanctions and positive inducements employed against Iraq, Iran, Libya, and North Korea since 1990, finding that sanctions have largely leveled off since the 1990–1994 period, while positive inducements spiked in the late 1990s and have declined since.[12] Fuhrmann and Kreps (2010) identify 21 dyad-years in which attacks against nuclear facilities occurred between 1941 and 2000. Following a number of attacks on nascent nuclear facilities in Germany during World War II, strikes peaked in the 1980s and 1990s, largely targeting Iraq. To this tally we can add at least Israel's strike against a Syrian nuclear reactor in 2007.

The trend in sanctions and other enforcement behavior, however, is necessarily related to the prevalence of nuclear pursuit; only when states are seen as seeking weapons can their behavior be punished. Since 1990, all non-weapons states with active nuclear weapons programs—Libya, Iraq, Iran, North Korea, and Syria—have been subjected to severe international sanctions designed to curb nuclear progress, military attack, or both. There can no longer be much doubt for proliferant states that the international community is likely to take strong action against covert nuclear weapons work, if such work is discovered.

Of course, attempts to use overt facilities to produce weapons are also likely to be discovered and punished.[13] But a state can mitigate the effect of this punishment by

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[12] As Reynolds and Wan (2012) point out, some of this trend can be explained by the removal of Iraq and Libya as sanctions targets by the early 2000s.

[13] It is worth noting that the ability of the IAEA to detect diversion from large nuclear facilities has been repeatedly called into question. This problem may be getting worse, as

limiting the amount of time it is vulnerable to sanction or attack before it has acquired a weapons capability. States pursuing overt pathways to a nuclear weapon will seek to minimize the breakout time between a shift to weapons work and actual production of a nuclear weapon. There is some reason to believe that this window of vulnerability has narrowed over time, and that this trend has recently become more apparent to states.

In the early years of the nuclear nonproliferation regime, a number of states contemplated a hedging strategy which would bring them close to a weapons capability using overt facilities. But it was not clear how close these states would be able to get to weapons work before their actions would be seen as suspicious or problematic by the international community. Australia, for example, assessed before signing the NPT that the treaty would allow it to get within 3 years of a nuclear weapon (Australia Department of Defence 1968).

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a limited pool of IAEA inspectors is called upon to safeguard larger and larger nuclear sites. Sokolski (2008) points out that the IAEA was responsible for inspecting six times the amount of weapons-usable plutonium and highly enriched uranium in 2004 than it was in 1984, but that the Agency's budget barely doubled in real terms. And it is not at all clear that the IAEA can detect diversion of material in a safeguarded facility with enough lead-time to allow for diplomatic efforts to stop nuclear weapons acquisition. "In fact, there is insufficient time [for] the IAEA staff to develop its report to the Board of Governors of the IAEA and for the Board of Governors to report to the UN Security Council." (Cochran 2008).

But if there had been any doubt remaining, the case of Iran made it quite clear that overt facilities could bring a state to within months or even weeks of a weapon's capability. By 2015, at the time of its agreement with world powers to limit its nuclear development, Iran had a substantial nuclear infrastructure in place. Its major nuclear sites included uranium mines and production facilities at Gachin, Saghand, and Ardakan; a uranium conversion facility and fuel manufacturing plant at Esfahan; uranium enrichment plants at Natanz and Qom; a research reactor in Tehran; a heavy water production facility and reactor at Arak; and a nuclear power reactor at Bushehr; among many other subsidiary and support facilities.[14] Experts assessed before the agreement that Iran could use these facilities to produce enough fissile material for a nuclear weapon in 2–3 months (The White House 2015).[15] Of course, Iran paid a substantial price for its nuclear development. Years of escalating sanctions had taken a toll on Iran's economy and contributed to Tehran's political isolation from the rest of the world.

But the international community's response to Iranian nuclear development was not a foregone conclusion. It hinged on a key development—the finding by the IAEA's Board of Governors in 2005 that Iran was in noncompliance with its commitments under

[14] For a discussion of major nuclear sites in Iran, see Nuclear Threat Initiative (2017).

[15] A major US goal in negotiations with Iran was to extend that breakout time to at least a year while the agreement was in force (The White House 2015). On whether breakout time alone is an appropriate metric for judging the Joint Comprehensive Plan of Action, see Kaplow and Gibbons (2015) and Vaez (2015).

the NPT (International Atomic Energy Agency 2005a). And the basis of this finding was not Iran's development of nuclear facilities alone, but rather its failure to declare these facilities to the IAEA. In the Iranian case, the cover-up was worse than the crime: Iran's nuclear infrastructure was in keeping with its NPT commitments, but its secrecy about those facilities was not. Iran would have faced strong pressure to limit its nuclear development in any case, but its failure to declare its nuclear facilities directly facilitated broad-based international sanctions that would have been difficult to achieve in the absence of a clear violation of its safeguards agreement.

Future nuclear aspirants might draw the lesson from this case that it is possible for states to acquire a latent nuclear weapons capability while still abiding by their NPT commitments. Iran was punished for its secrecy, but other states might simply declare their nuclear facilities in accordance with IAEA procedures and reap all the benefits of a full overt nuclear infrastructure. To the extent that the Iran case demonstrates that very short breakout timelines are possible, this makes overt pathways to a weapon more compelling to potential proliferants.

The relative benefit of overt pathways

The risk and consequences of detection capture the cost states bear by choosing covert pathways to a bomb. There also has been a shift, however, in the relative benefit of overt facilities versus secret alternatives. Because of changes in foreign nuclear supply, overt pathways in recent years may have become more likely than covert efforts to lead to advanced nuclear capabilities.

The nuclear nonproliferation regime itself has had an important deleterious effect on the provision of sensitive nuclear supply. In the early years of the nuclear age, nuclear weapons states did not hesitate to provide sensitive nuclear technology to allies, including assistance for explicitly nuclear weapons purposes (Kroenig 2010). The NPT prohibited weapons states from providing such assistance to non-weapons states. This provision was strengthened by the creation of the Nuclear Supplier's Group in the 1970s and the accession of longtime-holdouts France and China to the NPT in the 1990s. The result is that sensitive nuclear assistance from foreign suppliers is much harder to come by than in years past.[16] This dynamic tends to push proliferant states—especially those incapable of a fully indigenous nuclear development effort—toward overt facilities, where foreign supply is still a possibility.

States may also be placing increasing value on the flexibility offered by a hedging strategy that makes use of a civilian nuclear infrastructure. As international norms against the development of nuclear weapons have increased in strength over time with the broadening membership and substantive expansion of the nuclear nonproliferation regime (Knopf 2018; Rublee 2009), they may have become more likely to influence domestic debates about nuclear behavior (Cortell and Davis 1996). Given the widespread opprobrium that attends to nuclear weapons development, even leaders with

[16] North Korea, assessed to be the primary supplier of Syria's covert nuclear reactor (Office of the Director of National Intelligence 2008), may be the exception to this general rule.

strong nuclear weapons ambitions may have trouble assembling a domestic coalition in favor of a nuclear effort that is explicitly for weapons (Narang 2017). Selling key constituencies on a civilian nuclear infrastructure, at least as a first step, is potentially a much easier task.

Implications for nonproliferation policy

In this paper, I have argued that changes in nuclear proliferation dynamics have made overt pathways to nuclear pursuit more likely. If my theory is correct, it has significant implications for nonproliferation policy. Scholars and analysts have worried about this type of latent nuclear program for some time, but the nonproliferation community has not focused on several important implications of a world with more states on the verge of a weapons capability. Understanding the shifting proliferation landscape is essential to designing effective strategies for combatting proliferation, developing indicators of proliferation behavior, and assessing future proliferation risk.

The shift from covert to overt pathways complicates the task of analysts and scholars seeking to identify states of proliferation concern. The nonproliferation community has long relied on a variety of indicators of weapons intent—such as covert facilities, shadowy procurement activity, or the presence of weapons-usable materials—that we are unlikely to observe in a state that opts for an overt pathway to a weapon. Assessing proliferation risk in this environment will require a new set of probabilistic indicators of nuclear behavior, focusing on the broader political and security context rather than technical details. An increase in the prevalence of latent nuclear weapons capabilities also calls for a renewed emphasis on accurately evaluating breakout timelines given a particular set of overt capabilities.

Latent nuclear capabilities also place an additional burden on the IAEA-led nuclear inspection regime. The IAEA has steadily placed more and more emphasis on the presence of undeclared facilities in a state. While it is important to maintain this posture, the IAEA should also increase efforts to limit the gap between the start of breakout activities at safeguarded nuclear facilities and the time at which the IAEA becomes aware of these activities. The tools that will facilitate this shift are already available—unattended monitoring systems, more precise measurements to reduce material unaccounted for in nuclear plants, and rapid environmental sampling, for example—but these tools have not been made widely available for use in facilities that are not already considered a high priority.

IAEA inspectors also could better contribute to evaluating proliferation risk by providing the international community with more detail about potential breakout timelines. Currently, the major deliverable for the IAEA is the Agency's conclusion that all nuclear material in a state is being used for peaceful activities. But for a state with a latent nuclear capability, this conclusion is not particularly meaningful. States adopting an overt pathway to a weapon may be using all their material for peaceful activities and still be only weeks away from a weapons capability. A more useful deliverable in a world of nuclear latency would be a technical judgment about how close a state is to a weapons capability, and how quickly the IAEA would be capable of detecting any diversion or breakout attempt. The IAEA is uniquely positioned to provide that information to the broader nonproliferation policy community, although such a shift in emphasis would be likely to anger some member states.

Finally, the increasing prevalence of overt pathways to a weapon should shift the focus of institutional attention away from the NPT—which is poorly equipped to limit civilian nuclear capabilities—and toward other institutional arrangements, including bilateral agreements, that can more effectively place restrictions on nuclear supply. The NPT was designed with a guarantee of nuclear supply as one of its core pillars; one of the central bargains of the treaty trades nuclear forbearance on the part of non-weapons states for the provision of peaceful applications of nuclear technology. It is thus not surprising that states would be able to go right to the edge of nuclear weapons capability and still be in full compliance with their commitments under the NPT. Other institutions, however, such as the Nuclear Supplier's Group, are better positioned to put limits on trade in nuclear technology.

Better positioned still are the bilateral nuclear cooperation agreements that many recipient states enter into. These agreements—123 Agreements in the United States—are an effective way to designate some uses of nuclear technology as out-of-bounds, because they carry the immediate threat of cutting off nuclear cooperation if the rules of the agreement are not met. For example, the United States has previously insisted in its nuclear cooperation agreements that recipient states abide by the "gold standard" and agree not to engage in enrichment or reprocessing activities. This provision has not been adopted, however, in recent nuclear cooperation agreements.

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